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What would Darwin have written now?

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Abstract. We often wonder how many of the pristine places left on Earth we can protect from deterioration before it is too late. The assumption that remote regions remain pristine plays a key role in directing policies for regional environmental management and conservation, and affects the local and global financial impetus to do so. In this paper, we use Argentinean Patagonia and the SW Atlantic as examples to argue that the assumption '*remote region = pristine region*' is unjustified and based on a lack of information rather than on scientific evidence. We also discuss the major existing environmental threats to this supposedly 'pristine' region, and use emblematic examples to provide a more realistic picture of the regional environmental integrity and to set recommendations directed to improve environmental management and conservation within this context.

'*The plains of Patagonia…bear the stamp of having lasted, as they are now, for ages, and there appears no limit to their duration through future time*.' – Charles Darwin in *Voyage of the Beagle* (1831–1836).

We often wonder how many of the pristine places left on Earth we can protect from deterioration before it is too late, but less often wonder if there are any left. Usually, terms like 'pristine', 'wilderness', or 'wild' have deep cultural roots with hard-to-translate differences in their local meanings in different countries. Here we use the term *pristine* (unifying it to *wilderness* and *wild*), to refer to an area unaffected by humans and, therefore, containing native fauna and flora assemblages which are presumed to remain unaltered since before human populations spread worldwide. Scientists know that places like the Galapagos Islands, the Serengeti grasslands or the Caribbean coral reefs, although commonly considered to be pristine by the general public, are in fact highly disturbed. On the other hand, some regions are still considered pristine even by most scientists due to their remoteness from developed urban centres (Mittermeier et al. 2002). In this paper, we use Argentinean Patagonia and the SW Atlantic as examples to argue that the assumption '*remote region = pristine region*' is unjustified and based on a lack of information rather than on scientific evidence. We also discuss the major existing

environmental threats to this supposedly 'pristine' region, and use emblematic examples to provide a more realistic picture of the regional environmental integrity and to set recommendations directed to improve environmental management and conservation within this context.

Of all the regions globally and historically considered as remote and pristine, Patagonia and the SW Atlantic coastal and shelf habitats are among the most extensive. Because this region is sparsely populated, with relatively few industrialized areas and with a high abundance of charismatic fauna and flora, it is often regarded as Nature in its most pristine and desolate state at the uttermost end of the Earth (Rossi 2000; The Columbia Encyclopedia 2000). Visitors from all around the world are attracted to this region every year to see the hidden paradise that Darwin described in his voyage on the Beagle back in the early 1800s; and drastic regulatory decisions are directed toward keeping the region undisturbed by humans. However, a retrospective and realistic evaluation shows that due to a relatively low level of scientific activity and chronic brain drains for political and economical reasons (Kaiser 2002; Marzuola 2002; Perez-Iratxeta and Andrade 2002), the scientific information concerning the biology and environmental ecology of this region is geographically scattered, topically skewed and insufficient to support the idea that this region is 'pristine'. Moreover, unlike places like the Galapagos Islands or the Caribbean coral reefs, both scientists and the general public are mostly ignorant of the current state of environmental integrity of most of the Southern South American and SW Atlantic environments. In fact, existing local studies suggest that these areas are already dramatically disturbed by important human-mediated threats, as briefly discussed below:

Desertification and oil pollution: Heavy grazers such as cows, sheep, reindeer, and feral goats have been repeatedly introduced during the last century with negative consequences for local environmental integrity (Aagensen 2000; Jaksic et al. 2002). For example, from the time of their introduction in the late 1800s, the number of sheep in Patagonia dramatically increased from zero to over 22 million in just a few decades (with much higher stocking levels than presently), after which it stabilized to about 8 million where it has remained until the present time (Aagesen 2000; INDEC 2005). Wind erosion combined with destructive sheep grazing and fires has resulted in serious soil degradation, causing a loss of the organic soil horizon and reducing the land's fertility and capacity to absorb and retain water. Presently soil erosion is widespread, and the flora has been so extensively modified that our ability to determine the composition and characteristics of Patagonia's vegetation before European contact is severely compromised or null. Human-induced fire may date back to 8000 years B.P. in Patagonian ecosystems, but with European settlement it was increasingly used as a management tool for productive purposes (Veblen et al. 1999). The frequency with which Patagonian lands have been burned and the extent of the surface burned each year has varied over time, but both frequency and extent have doubled during the last 5 years (Dentoni 2001). The result of these processes operating together is that over 84.4% of Patagonia is currently

moderately to very severely degraded by desertification (*sensu* del Valle et al. 1998). Another presumably important disturbance in this region is oil spills. Although the offshore petroleum activity on the SW Atlantic and Patagonian shelf is not extensively developed yet, oil spills have already strongly impacted the coast of Patagonia and many austral islands. Between 1974 and 1991 more than 86,500 tons of crude oil were spilled in the region and at least two oil tankers exploded in or near harbour areas with dramatic negative consequences for local ecosystems (Esteves et al. 2000). Between 1983 and 1991, at least 41,000 penguins died due to oil pollution in central Patagonia with highest counts of 49 dead penguins per kilometre of coast (Gandini et al. 1994); in September 1982, 15 linear km of native kelp forests were covered by crude oil at Bustamante Bay; and in 1992 the intertidal in the Magellan Strait still remained covered by extensive coating of tar that originated from an oil spill 18 years earlier (Esteves et al. 2000).

Tourism exploitation: Of the 29 marine protected areas (MPAs) existing in Patagonia where seabirds and mammals feed, rest and reproduce, at least 27 of them are frequently visited by organised and *dis*-organised tourism (Yorio 2001; Yorio et al. 2001). From 1992 to 2003 the number of visitors in 8 of these MPAs doubled from 140,000 to 280,000 and the number of cruise ship passengers visiting the region has increased threefold or more (data source: Provincial Tourism Secretary of Chubut, http://www.chubutur.gov.ar; Figure 1b). This massive tourism-associated exploitation of MPAs has historically supplied a favourable input to the local economy and general development (Yorio et al. 2001), but it is likely to alter the integrity of local ecosystems due to the lack of well-developed regional coordination of management planning and regulation.

Fisheries: The overexploitation of fisheries resources is among the more dramatic problems in the SW Atlantic (Figures 1 and 2). By the mid 1970s the total catch of fish and invertebrates reached 1 million metric tons (mt), and the catch has doubled since 1987. Up to the 1980s, the most commercially important species were the hakes *Merluccius hubbsi* and *M. polylepis*. These were regionally overexploited by the mid 1990s (Esteves et al. 2000). After 1982, Argentina and the UK increasingly exploited the squids *Illex argentinus* and *Loligo* spp., and 5 years later the squid stocks were considered overfished, probably due to the activities of illegal fishing fleets concentrated in the area (Bisbal 1995, Figure 2). Consequently, the catch of squid decreased from 750,000 to 552,000 mt between 1989 and 1990 (FAO 1992). These are emblematic regional examples of devastating overexploitation by international fisheries (Sea Around Us Project: http://saup.fisheries.ubc.ca/lme; Figures 1a and 2), with doubtful sustainable benefits for the local and global economy, and with negative consequences expected for marine communities and ecosystems (Dobson et al. 1997; Coleman and Williams 2002).

Exotic species: The introduction of exotic species is another unbalanced pressure affecting the functioning of regional ecosystems (Jaksic et al. 2002; Orensanz et al. 2002; Pascual et al. 2002; Figure 2). The decreasing abundance of native species combined with an increasing presence of exotic species is likely

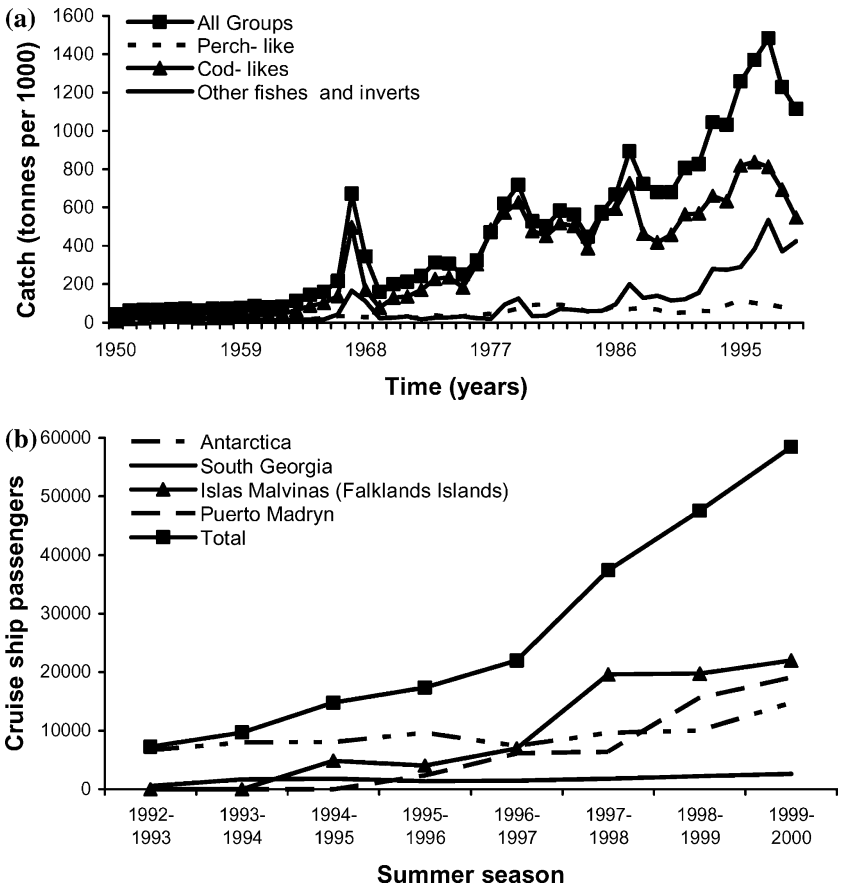

Figure 1. (a) Catch of different marine resources in the Patagonian shelf ecosystem from 1950 to 1999 (Data Source: Sea Around Us Project: http://saup.fisheries.ubc.ca/lme/SummaryInfo.aspx?LME=14#). The 'all groups' category includes fish, molluscs and crustaceans. (b) Number of cruise ship passengers arriving in the summer tourist season in [1]Antarctica, [2]South Georgia, [3]Islas Malvinas (Falkland Islands) and [3]Puerto Madryn (Argentina) from 1992 to 2000. ([1]http://www.iaato.org/tourismstatistics/Trends9203BW.doc, [2]Ingham and Summers 2002; [3]Prefectura Naval Argentina y Administración Portuaria de Puerto Madryn, Argentina). Cruise ships dock at several ports along the Patagonian coast, which increases tourist pressures on the local environments.

affecting native communities and generating novel assemblages with uncertain structuring processes (Schwindt et al. 2001; Orensanz et al. 2002). One result of these processes is that top-level predators such as the Malvinean fox *Dusicyon australis*, the jaguar *Panthera onca* and the South American lion *Felis concolor* are now scarce or extinct (Chebez 1994). Within Patagonia, eight species of exotic terrestrial mammals (including hares, rabbits, deer, minks, beavers, rats and foxes), were introduced between 50 and 100 years ago (Jaksic et al. 2002). Today, their spread rates range from 2.7 km/year for the American

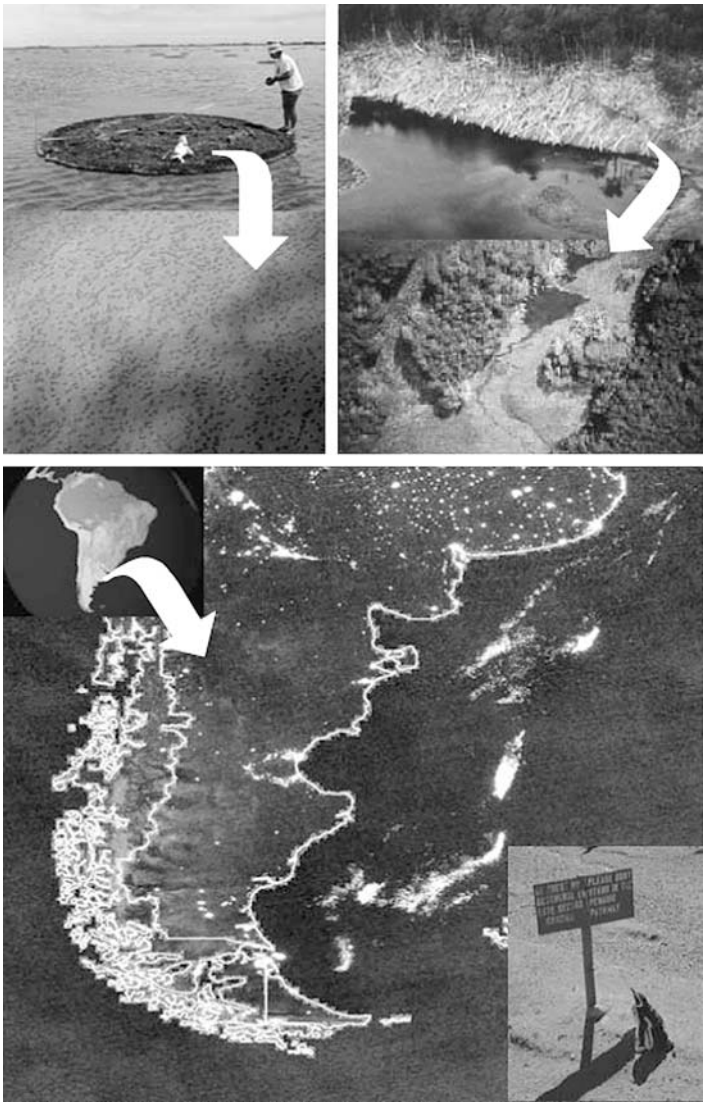

Figure 2. Factors affecting Patagonian and SW Atlantic ecosystems. **Top right:** Dam built in a river in Tierra del Fuego by the introduced Canadian beaver. **Top left:** Fifty years after its introduction, the exotic reef-building polychaete *Ficopomatus enigmaticus* now dominates the Mar Chiquita coastal lagoon in Argentina. The ~2 m wide circular reefs concentrate in large densities altering the geomorphology, with dramatic consequences for community and ecosystem dynamics. **Bottom right**: A Magellanic penguin seems to watch a 'please, don't stand in the penguin pathway' sign in the Marine Protected Area Punta Tombo (Central Patagonia). **Bottom-Centre:** Squid fishing vessels as seen from space at night in a satellite image (summing all nights from 2002 in this single figure). The fishing fleets – legal and illegal, from over 20 countries – use lights to attract squid and span a vast area along the continental shelf break many times larger than any populated area on the continent.

beaver *Castor canadensis* to 20 km/year for the European hare *Lepus europaeus*. Several of the introduced exotic plants and animals are ecosystem engineers and have originated dramatic changes in the structure of native communities and local landscapes, leading to a need for thorough scientific assessment and analysis (e.g., Lizarralde and Escobar 2000, Figure 2). For example, in Tierra del Fuego the American beaver destroys and inundates the native *Nothofagus* forests (Lizarralde 1993) and alters the forest's nutrient dynamics (Lizarralde et al. 1996). On the SW Atlantic coast, over 33 exotic marine species have been reported. Of these, 7 have already been shown to have ecological impacts on native communities, and further research will likely reveal impacts from many of the others (Orensanz et al. 2002). The introduced barnacle *Balanus glandula* has shown an even faster rate of spread than terrestrial organisms, colonizing over 10 degrees of latitude at a rate of 70 km/year (Schwindt and Bortolus 2004). Invasive kelp forests of *Undaria pinnatifida* are modifying the composition of native subtidal communities with uncertain magnitude (Casas et al. 2004), and indirectly affecting the local artisanal fisheries and scuba diving ecotourism – a major local tourist industry. Because Patagonia is known for its 'pristine' wilderness, ecotourism has historically provided large economic inputs to regional development; but paradoxically, in some cases this same tourism has also promoted species introductions. For example, in most Patagonian National and Provincial Parks exotic freshwater fishes have been repeatedly introduced for tourist-oriented sport fishing (Pascual et al. 2002), and similarly happened with exotic mammals (Jaksic et al. 2002). Presently, over 10 exotic predator fish species are populating rivers, lakes and reservoirs throughout Patagonia, while the native freshwater ictiofauna is currently restricted to only 20 species (Pascual et al. 2002).

Regionally unbalanced scientific development: We consider this as potentially the worst threat to environmental integrity, for the latter depends on the general balance and internal coherency of scientific development. In Argentinean Patagonia, as in most remote regions worldwide, a long tradition of grants and funding directed to support the protection (Figure 2) and autecological study of charismatic animals has delayed the development of more integrative ecological and ecosystem perspectives. In accordance with this history, the MPAs along the SW Atlantic coast were conceived with the idea of protecting and preserving charismatic flag species of seabirds and marine mammals which, conveniently, were commonly concentrated in small coastal areas (Yorio 2001). With the creation of new lines of integrative and ecosystem-based research nationwide during the last few years of economic and scientific development, it has become increasingly evident that most coastal environments in this region remain largely unknown to community and ecosystem ecologists. In fact, while charismatic organisms such as elephant seals, sea lions, cormorants and penguins are counted, measured and tracked through radio satellite technology every year, virtually no data is collected about the patterns and processes shaping the mudflat, cobble, sandy and rocky

shore ecosystems in which they are embedded. In other words, we are able to determine where and how many molluscs and crustaceans can be eaten by marine mammals and seabirds during a breeding season, but nothing is known about how these interactions affect the structure of the benthic communities. A more dramatic example of the highly unbalanced scientific development in Patagonia is illustrated by the austral salt marshes, whose physiographic and ecological patterns were first described only in 2005, after being completely ignored by community and ecosystem ecologists for over two centuries (Bortolus 2005). Management decisions based on inaccurate or even absent information have often lead to decisions that fail to protect and may even lead to further degradation of the natural environment (e.g., Faber 2000). Local examples of this are the creation of intangible nature reserves in areas where exotic species have already become well-established (e.g., Orensanz et al. 2002), or where other overlooked disturbances have been operating for centuries. Paradoxically, local controls intended to protect natural areas commonly fail to prevent illegal intrusion of hunters/fishers, tourists and other causes of disturbance, while such controls simultaneously, through bureaucracy and highly discouraging restrictions, often stop or delay scientific research which might lead to improved strategies for protection (Pascual et al. 1998).

In this paper we have shown that the information available, although unarticulated in space and time and poorly divulged, is sufficient to knock down the idea of a pristine Patagonia-SW Atlantic. Far from being apocalyptic, this conclusion reminds us that while it seems theoretically improbable that any remote region on Earth remains truly pristine, such regions certainly remain interestingly mysterious and in need of thorough scientific attention. Presently, it is hard to assign a specific conservation value to Patagonia, for its many native endemic plants and animals and its vast landscapes devoid of large urban centres are under an uncertain but increasing level of regional disturbance. Part of these disturbances (e.g., the massive tourism and fisheries) evidence the existence of a variety of valuable ecosystem services already being exploited and protected. However, is for how long these ecosystem services will be sustainable, what it needs to be individually evaluated. A preliminary step to cope with this regional problem on a global scale is supporting/funding and promoting well-coordinated regional surveying projects of remote regions in order to (a) update environmental descriptions using a multidisciplinary approach, (b) conduct a more complete evaluation of the real magnitude of the existing environmental disturbances/threats, (c) describe the new community assemblages and regulatory processes present after exotic introductions, and (d) assess new values for regional ecosystem services. Locally, a more effective effort should be undertaken to integrate governmental agencies and scientific institutions in order to avoid mutually obstructive policies and activities.

The assumption that *remote region = pristine region* makes impossible to develop effective local and global environmental policies by delaying the design of appropriate social and scientific legislation to study and protect impacted areas, and by favouring the use of misinformation as scientific evidence. Only

by updating the ecological and evolutionary understanding of these remote regions will it be possible to delineate effective global policies in order to best study and preserve them.

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References

Aagensen D. 2000. Crisis conservation at the end of the world: sheep ranching in Argentine Patagonia. Environ. Conserv. 27: 208–215.

Bisbal G. 1995. The southeast south American shelf large marine ecosystem. Mar. Policy 19: 21–38.

Bortolus A. 2005. Finding a lost world in the mythic Patagonia: setting physiographic and ecological baseline information of the austral salt marshes of South America. *XXX Jornadas Argentinas de Botanica*. Rosario, Argentina.

Casas G., Scrosati R. and Piriz M.L. 2004. The invasive kelp *Undaria pinnatifida* (Phaeophyceae, Laminariales) reduces native seaweed diversity in Nuevo Gulf (Patagonia, Argentina). Biol. Invasions 6: 411–416.

Chebez J.C. 1994. Los que se van. Albatros, Buenos Aires.

Coleman F.C. and Williams S.L. 2002. Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends Ecol. Evol. 17: 40–44.

del Valle H.F., Elissalde N.O., Gagliardini D.A. and Milovich J. 1998. Status of desertification in the Patagonian region: assessment and mapping from satellite imagery. Arid Soil Res. Rehabil. 12: 95–122.

Dentoni M. 2001. Fire Situation in Argentina. In: Goldammer J.G. and Mutch R.W. (eds), FRA Global Forest Fire Assessment 1990–2000. Forest Resources Assessment Programme, Working Paper 55 FAO, Rome, pp. 457–462.

Dobson A.P., Bradshaw A.D. and Baker A.J.M. 1997. Hopes for the future: restoration ecology and conservation biology. Science 277: 515–522.

Esteves J.L., Ciocco N.F., Colombo J.C., Freije H., Harris G., Iribarne O., Isla I., Nabel P., Pascual M.S., Penchaszadeh P.E., Rivas A.L. and Santinelli N. 2000. The Argentine Sea: the southeast South American shelf marine ecosystem. In: Sheppard C.R.C. (ed.), Seas at the Millenium: An Environmental Evaluation. Pergamon, New York, pp. 749–771.

Faber P. 2000. Grass wars. Good intentions gone awry. Why would anyone bring an alien cordgrass into S.F. Bay? California Coast and Ocean 16: 14–17.

FAO 1992. Review of the state of the world fishery resources. Part 1: The marine resources FAO Fisheries Circular, No 710, Rev 8, Part 1, Rome.

Gandini P., Boersma P.D., Frere E., Gandini M., Holik T. and Lichtschein V. 1994. Magellanic penguins (*Spheniscus magellanicus*). Affected by chronic petroleum pollution along the coast of Chubut, Argentina. Auk 111: 20–27.

INDEC 2005. Instituto Nacional de Estadísticas y Censos. http://www.ndec.mecon.ar/.

Ingham R.J. and Summers D. 2002. Falkland Islands cruise ship tourism: an overview of the 1999–2000 season and the way forward. Aqua. Conserv. Mar. Freshw. Ecosyst. 12: 145–152.

Jaksic F.M., Iriarte J.A., Jiménez J.E. and Martínez D.R. 2002. Invaders without frontiers: cross-border invasions of exotic mammals. Biol. Invasions 4: 157–173.

Kaiser J. 2002. Argentina: economic crash brings ill winds for science. Science 295: 2356.

Lizarralde M.S. 1993. Current status of the introduced beaver (*Castor canadensis*) population in Tierra del Fuego, Argentina. Ambio 22: 351–358.

Lizarralde M.S. and Escobar J.M. 2000. Mamíferos exóticos en la Tierra del Fuego. Ciencia Hoy 10: 52–63.

Lizarralde M.S., Deferrari G.A., Alvarez S.E. and Escobar J.M. 1996. Effects of beaver (*Castor canadensis*) on the nutrient dynamics of the southern beech forest of Tierra del Fuego (Argentina). Ecol. Aust. 6: 101–105.

Marzuola C. 2002. Argentina's crisis heralds time of torment for scientists. Nature 415: 104.

Mittermeier R.A., Mittermeier C.G., Robles-Gil P., Pilgrim J., da Fonseca G.A.B., Brooks T. and Konstant W.R. 2002. Wilderness. Earth's Last Wild Places. CEMEX, Mexico.

Orensanz J.M., Schwindt E., Pastorino G., Bortolus A., Casas G., Darrigran G., Elías R., López Gappa J.J., Obenat S., Pascual M., Penchaszadeh P., Piriz M.L., Scarabino F., Spivak E.D. and Vallarino E.A. 2002. No longer a pristine confine of the world ocean-a survey of exotic marine species in the Southwestern Atlantic. Biol. Invasions 4: 115–143.

Pascual M.A., Orensanz J.M., Parma A. and Saba S.L. 1998. The Patagonian challenge: melding conservation with development. In: Fiedler P.L. and Kareiva P.M. (eds.), Conservation biology for the coming decade. Chapman and Hall, New York, pp. 410–425.

Pascual M., Macchi P., Urbanski J., Marcos F., Riva Rossi C., Novara M. and Dell' Arciprete P. 2002. Evaluating potential effects of exotic freshwater fish from incomplete species presence-absence data. Biol. Invasions 4: 101–113.

Perez-Iratxeta C. and Andrade M.A. 2002. Worldwide scientific publishing activity. Science 297: 519.

Rossi J. 2000. The wild shores of Patagonia: the Valdes peninsula and Punta Tombo. Abrams, H.N.

Schwindt E. and Bortolus A. 2004. Evaluando la predictibilidad de los patrones y procesos ecológicos con especies exóticas: comparación entre áreas de origen e invadidas. II Reunión Binacional de Ecología Argentina y Chile, Argentina, p.74.

Schwindt E., Bortolus A. and Iribarne O. 2001. Invasion of a reef-builder polychaete: its direct and indirect impacts on the native benthic community structure. Biol. Invasions 3: 137–149.

The Columbia Encyclopedia 2000. In: Lagasse P. (ed.), 6th edn. Columbia University Press.

Veblen T.T., Kitzberger T., Villalba R. and Donnegan J. 1999. Fire history in northern Patagonia: the role of humans and climate variations. Ecol. Monogr. 69: 47–67.

Yorio P. 2001. Areas marinas protegidas en la Argentina. Ciencia Hoy 11: 32–38.

Yorio P., Frere E., Gandini P. and Schiavini A. 2001. Tourism and recreation at seabird breeding sites in Patagonia, Argentina: current concerns and future prospects. Bird Conserv. Intern. 11: 231–245.